Heterodyne Spectroscopy in the Far-Infrared at KOSMA

Submillimeter, far-infrared, and even mid-infrared heterodyne spectroscopy is a rapidly developing method to obtain very detailed information about the varying conditions in the interstellar medium. With the nowadays available high sensitivity of heterodyne mixers the details of velocity structures become accessible by means of high resolution real time spectrometers with very good signal to noise. Broad-banded spectrometers, particularly acousto-optical spectrometers (AOS), are one of the key elements for this task. At KOSMA (Koelner Observatorium für Sub-Millimeter Astronomie) we have intensified our efforts to meet the needs of high numbers of high resolution spectrometers as well as of very broad-band spectrometers. A first step was the fabrication of a 1.4 GHz bandwidth AOS for the NASA SWAS mission (Submillimeter Wave Astronomy Satellite) 10 years ago. This AOS has served for five years of continuous operation for the observation of H_2O, ^{13}CO, CI, and O_2 in various astronomical sources until December 2003. A further step was made with the design of a 4-band "Array-AOS", which is in use now at observatories like KOSMA, AST/RO, and CSO. A space qualified version of this instrument is also in preparation for the HIFI (Heterodyne Instrument for the Far-Infrared) instrument on ESAs Herschel mission. It will provide two times 4 GHz coverage as a hybrid system for the various HIFI bands ranging from 500 to 1900 GHz. At the same time up to four such spectrometers are being built for the GREAT system (German REceiver for Astronomy at Terahertz frequencies) and for future imaging receiver systems as well. Future programs in the THz frequency range on ground and in space will require spectrometer bandwidths of several GHz, and it is evident that new developments are needed to meet these demands. This is particularly true for the mid-infrared region, where we presently are operating a "Tunable Heterodyne Infrared Spectrometer" (THIS) for the detection of molecules without permanent dipole moment like H_2, CH_4, CO_2, C_2H_2, ... THIS is presently being used around 10 _m wavelength, but attempts are on the way to observe at 17_m in order to detect the S(1) rotational quadrupole line of molecular Hydrogen. With SOFIA, also the S(0) Hydrogen line at 28 _m will become accessible. The extremely high resolution capability of heterodyne detection up to $R \sim 10^7$ will allow to study details of absorption features of very cold interstellar molecular Hydrogen, and to determine accurately the abundance and the ortho- to para-ratio of H_2 in these areas.